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Application of Friction Energy Consumption Support in the Project

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Abstract

Friction energy consumption support is an effective passive control technique with excellent promotion & application value for friction energy consumption reinforced concrete support system with low cost. Affiliate building of Service Commanding Center of Armed Police Frontier Corps is applied for friction energy consumption support in the project. There are 68 energy dissipaters for the project. In this paper, Installation techniques of energy dissipater and layout of energy consumption support have been introduced by aiming to energy consumption support characteristics. Structures of frame shear wall and energy consumption support frame have been also contrasted and analyzed to provide useful experience for other similar projects.

Keywords: Energy consumption support; energy dissipater; diagonal rod; supporting platform; friction energy consumption support device

1. Introduction

The project is commanding center building of Yunnan Security Guard Frontier Defense Corps and it is 4km away from Dianchi Road in Kunming. Commanding center building is a landmark with multiple functions such as anti-terrorist, capture drug smugglers, network scout and police information commanding treatment, etc. The entire project includes office building, affiliate building and multifunction hall. Affiliate building includes meeting room, dormitory and other multifunction rooms. It can be divided into middle building, left and right buildings by temperature joints. Friction energy consumption support frame structure system also shall be adopted to meet seismic design requirements.

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Fig.1. The appearance of the commanding center building

With T-form layout for the entire affiliate building, it is frame structure. Basement of office building is garage and power distribution room. There are 9 floors above the ground and the 1st to 2nd floors are hall, history hall, meeting room and office. The 3rd to 8th floors are office zone and the 9th floor is provincial video network commanding center and studio. There are 9 floors for affiliate building and it is armed police officers' refectory and dormitory living quarters. There is 1 floor for multifunction building and it is location of meeting and large-scale activities. Length is 44.9m and width is 14.4m for Section A. Length is 33.25m and width is 10.3m for Section B. There are 9 floors for Section A & B and height of the 1st and 2nd floor is 5.0m and 4.2m respectively. Height of the 9th floor is 4.5m and 3.6m for others. Total building height is 35.3m. Total building area is 30146m2. Sections A and B are connected in temperature joints and elevator hoistway is set in the middle of Section A. There is a main building elevator near elevator hoistway. There is also a secondary stair in the end of Section B.

Seismic fortification intensity is 8° and design earthquake group is the 2nd group. Design basic earthquake acceleration is 0.2g. With Class III site, characteristic cycle is 0.55s. It is designed by Guangzhou Baiyun Architectural Design Institute Co., Ltd. The 1st to 3rd concrete floors of Section A or B of beams or slabs are made of C35 and the 4th to 9th floors are made of C30. The 1st to 4th floors of supporting concrete are made of C40 and the 5th to 8th floors are made of C35. The 9th to 10th floors are made of C30 and materials of infilled wall are light concrete hollow bricks. There is only 1 span for Section A or B of building toward Y direction (short direction) and it belongs to adverse seismic structure. Friction energy consumption support is mainly set toward short direction (Y direction) of building. There are 32 energy consumption supports toward Section A. Of which: There are 14 ones toward X direction and 18 ones toward Y direction. There are 21 energy consumption supports toward Section B and they are set along Y direction. There are 68 ones for Sections A & B and friction energy consumption support forms include Type I, II and III. There are XC1~ XC35 supporting forms. Energy consumption support effect can be used to limit lateral deformation of framework so that it is controlled within a permissible scope. Energy dissipater can be set to control anticipated structural deformation to avoid severe destruction for main structure under elastoplastic earthquake. A lot of earthquake energy is consumed for friction energy consumption support device to improve seismic performance of framework structure and protect main framework[1]. It has to use energy consumption support so that layered elastic molding displacement angle of framework structure can meet anticipated deformation control requirements according to "Code for Seismic Design of Buildings" (GB 50011—2010). Structure without energy dissipater shall reduce properly to increase structural seismic ability and reduce cost greatly.

2. Layout of Energy Consumption Support and Installation of Energy Dissipater

Energy consumption support system mainly consists of upper and lowers diagonal rods, supporting platform, pre-buried pieces and energy dissipater.

Please refer to Type (I) shown in Figure XC8 for installation sketch. Diagonal support mode shall be adopted under general conditions. Dimension of platform section in the middle of energy consumption support can be determined after determining floor height and span of framework according to thickness required for installation unit of energy dissipater. Many energy dissipaters also can be installed on 1 platform section according to demand.

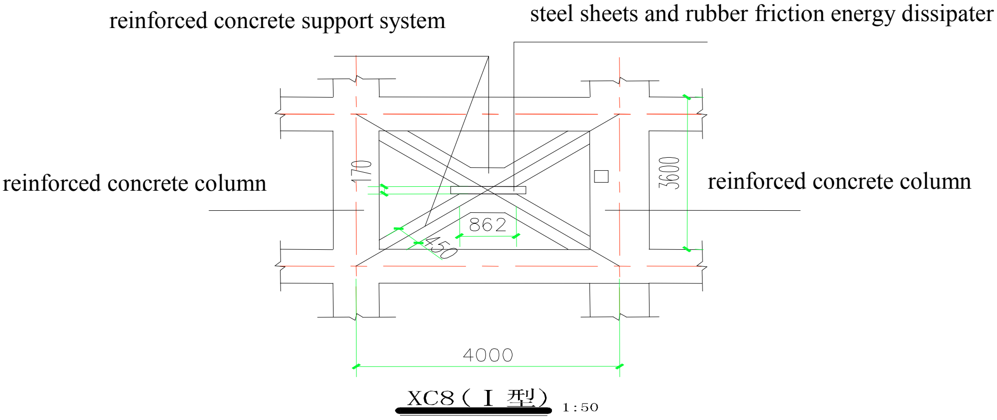


Fig.2. Type (I) shown in Figure XC8 for installation sketch

Binding photo of reinforcing steel bar of diagonal rod for reinforced concrete support is shown in following figure. There is certain deviation for design and position of pre-buried reinforcing steel bar of some supports in actual project. Upper and lower diagonal rods are not within the same plane. Gap caused by deviation in beam & column nodes can be filled by concrete for little deviation. Filling height can be 400mm to 500mm. Concrete strength level is the same to that of supporting rods. It has to remove original reinforcing steel bar and set it again for large deviation. Quantity, diameter and strength level of bonded rebus are the same to those of tubing of supporting rods.

Fig.3. Binding photo of reinforcing steel bar of diagonal rod for reinforced concrete support

Net gap of platform between upper and lower supporting rooms which is 170mm can meet design requirements strictly during construction. It has to guarantee sufficient length of supporting platform for support with little span and height. Angle of supporting rods can be adjusted properly. Small column shall be born on upper supporting rod and upper and lower supports cannot be threaded by small column for position overlapping of supporting rods and small column below platform beam in the staircase for the project.

The best installation chance of energy dissipater is after completion of main structure and before commencement of sorting works such as decoration. Interior and exterior decoration engineering has been done partially for affiliate building for construction of energy consumption support and installation of energy dissipater. Operation space is reserved in 2 sides of energy dissipater. Of which: The 1st and 16th axles are gable walls. It has to erect scaffolds from outside and detach stair platform beam which hinders installation. It also shall be restored after installation of energy dissipater.

General form of friction energy consumption support device in the frame is shown in above figure. It consists of supporting diagonal rod and energy dissipator. Energy dissipator will not start up under large earthquake before meeting startup conditions. Effect is equivalent to rigid tension rod and the entire device has basically identical effect for ordinary support. Lateral resistance rigidity of structure increases and lateral displacement of framework structure under normal usage conditions reduces. Energy dissipator starts up after meeting startup conditions. Damp, friction and plastic deformation performance can be utilized to dissipate earthquake energy. Please refer to sketch for friction energy consumption support device which protects main framework.

Detailed assembly process of friction type energy dissipator of steel sheets is shown as follows: It has to overlap 3 layers of steel sheets and 2 layers of rubber which constitute energy dissipator according to sequence then place them on assembly platform after simple fixation by assembly bolts. It has to exert determined pre-pressure on upper and lower layers of steel sheets of energy dissipator then monitor the value. It has to tighten bolts used for assembly of energy dissipator which are similar to tension and anchorage links during exertion process of pre-stress for members so that pre-pressure which exerts on upper and lower layers of steel sheets of energy dissipator varies even reduces. Fastenering force between steel sheets of energy dissipator and sheetrubber shall be controlled precisely according to variation of pre-pressure which exerts on upper and lower layers of steel sheets. It also has to detach upper or lower layer of steel sheets.

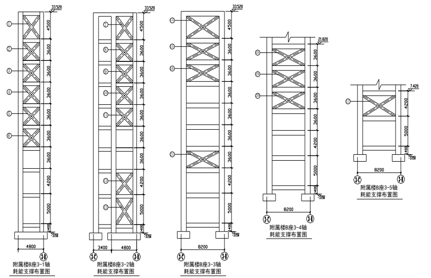
Fig.4. Section A of energy dissipater of friction energy consumption support (left)
Fig.5. Layout of energy consumption support of Building B (right)

Device can be installed on the site by following sequence: It has to install upper or lower diagonal rod of energy consumption support firstly then set pre-buried pieces of M1, M2 & M3 in suitable positions of horizontal section of upper or lower diagonal support. It has to set template for lower diagonal support then connect pre-buried bar of main framework and bind lower diagonal support reinforcement. It has to set template for upper diagonal support, connect main framework and bind diagonal support reinforcement on reinforced concrete. Concrete shall be poured and maintained to reach high strength. It has to install upper diagonal rod for energy consumption support then set pre-buried pieces of M1, M2 & M3 of energy dissipater in suitable position of horizontal section of diagonal support to ensure that upper or lower parts of diagonal rod are within the same plane with little tolerance. It has to bind reinforcing steel, pour and maintain concrete to guarantee high concrete strength. It has to install energy dissipater into gap of 170mm in horizontal section of reserved diagonal support then cushion by wooden cushion blocks. It has to fix steel sheets in middle layer of energy dissipater to pre-buried pieces in lower limb of diagonal support by large bolts then embed small steel sheets into reserved opening of upper layer of steel sheets. It has to weld small steel sheets on pre-buried pieces on upper limb of diagonal support. Energy dissipater and upper or lower pre-buried pieces can be welded by 3 layers of steel sheets with thickness of 35mm. It is also emphasis and difficulty during construction of energy dissipater. With Grade 2 welding joint level, complete penetration groove butt weld shall be adopted. Super-thick steel sheets shall be welded in layers and batches to guarantee high quality of flat welding joints without bubble, peeling or crack to meet regulations of “Code for Construction Examination & Acceptance” and ensure that welding joints can meet corresponding strength.

Abraded sheet rubber in energy dissipater shall be replaced if a lot of earthquake force shall be consumed for energy dissipater under strong earthquake.

(No. of lower energy dissipaters can correspond to 3-10 and 3-9 axles respectively.)

Layout of energy dissipater for the project is shown in above and below figures.



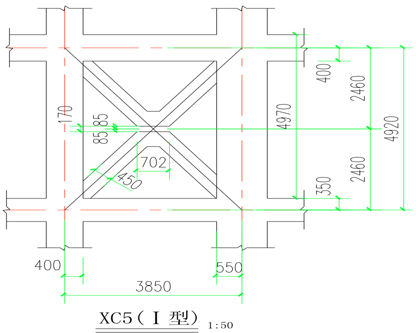
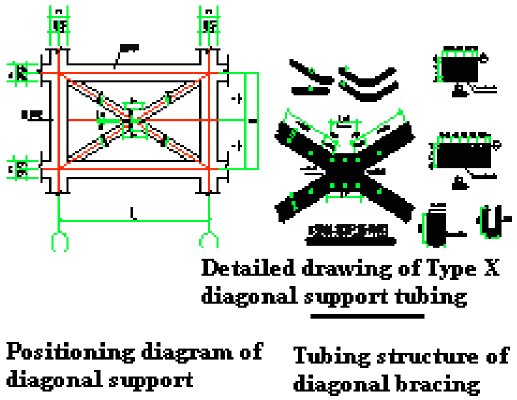


Fig.6. Layout of energy consumption support of Building B (left)

Fig.7. XC5, Type I energy consumption support (right)

Fig.8. Installed good energy dissipater (left)

Fig.9. Finished products welded by steel sheets of 35mm for energy dissipater (right)



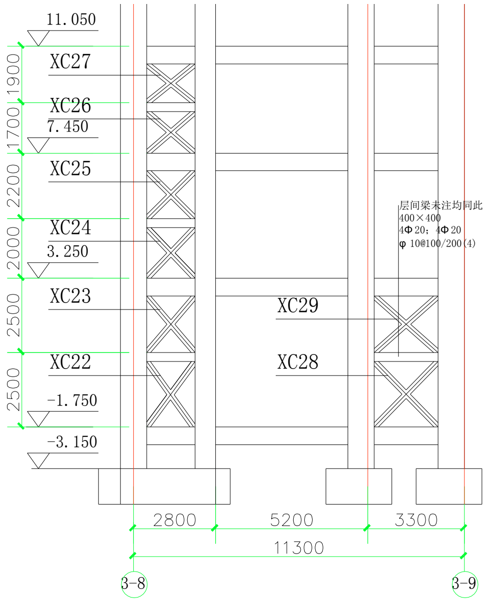


Fig.10. Type II (or III) X diagonal bracing (left)
Fig.11. layout of energy consumption of 3-B axle of affiliate building (right)

3. Contrast & analysis of energy consumption support framework and frame-shear wall structure

There is little shear weight ratio for Section A or B of building under effect of elastoplastic earthquake after test mainly due to long natural vibration cycle and characteristic cycle of 0.55s away from the site. Energy dissipater also starts up under effect of elastoplastic earthquake for the structure to reduce lateral rigidity and increase self-vibration cycle so as to reduce structural earthquake reaction. In addition, layered displacement angle is less than limitation shown in the code under effect of elastoplastic earthquake to meet fortification standard of “no collapsing under large earthquake”. Layered displacement is less than limitation shown in the code greatly. The structure also will deform without collapsing ability for main structure. It has high safety reserve mainly due to consumption of a lot of earthquake input energy after startup of energy dissipater.

2 structures can be designed by ordinary method due to excellent operation performance and low cost to support strong earthquake effect for framework structure. The same seismic wave can be selected for time interval analysis under effect of elastoplastic earthquake. It also has to contrast seismic reaction of the structure, consumption of engineering materials and energy consumption support framework structure. The project is located in 8° seismic fortification zone and there is only 1 span toward short direction of building. It belongs to adverse seismic structure and framework-shear wall structure system shall be at least adopted during ordinary design to meet seismic fortification requirements. It also can protect main structure against further destruction after test & contrast. It shows that energy consumption support framework has excellent ability to resist elastoplastic earthquake clearly.

With large lateral rigidity for framework-shear wall structure and base shear force for corresponding structures, shear weight ratio increases that of energy consumption support framework structure greatly [2]. In addition, elastic plastic displacement angle of the structure under effect of elastoplastic earthquake is less than limitation shown in the code to meet seismic fortification requirements of “no collapsing under large earthquake”.

4. Comparison of material consumption between framework-shear wall structure and energy consumption support framework structure

From previous analysis result we can see that energy consumption support framework and framework-shear wall can be adopted for the project respectively to meet seismic fortification requirements in 8° zone. We will proceed well with statistic contrast for 2 kinds of materials with different structural form demand. As shown in following form, only concrete consumption of column, support and shear wall have been compared due to no adjustment of beam slabs when designing framework shear wall.

Table 1.Concrete consumption form of framework-shear wall structure and energy consumption support framework structure

Item	Concrete quantity of Section A		Concrete quantity of Section B	
	Energy consumption support framework	Framework-shear wall	Energy consumption support framework	Framework-shear wall
Column	408.2	289.8	270.3	186.1
Shear wall		432.0		225.9
Support	57.2		37.9	
Total quantity	465.4	721.8	308.2	412.0
Difference	55.09％		33.68％	

From table1 we can see that concrete consumption required for energy consumption framework structure is less than that of framework-shear wall structure greatly. Related data also shows that energy consumption support framework structure can be adopted in high intensity zone. Required concrete or reinforcement consumption is less than that of framework-shear wall structure to save reinforcing steel bar which is originally used for shear wall by more than 50%. Cost can reduce effectively for concrete effectively without including reinforcing steel bar in concrete. Of which: Concrete can be saved by 55.09％ for Section A and 33.68％ for Section B with obvious economic benefits.

There are surely strict technical conditions for manufacturing & installation of energy consumption support in energy consumption support framework structure system to increase project cost while limited increase. Therefore, it has to create conditions for industrialization and canalization of energy consumption support by striving to improve energy consumption support form, manufacture materials and reduce technical requirements. Energy consumption support framework system also can be adopted to reduce project cost greatly [3].

The building is located in high seismic intensity zone. In general, framework-shear wall structure system shall be adopted during ordinary design. Therefore, elastic plastic analysis shall be done for the project after structural design of framework-shear wall. It has to compare with operation performance and consumption of engineering materials under earthquake effect of energy consumption support framework structure and framework-shear wall structure. Result also can show the equivalent ability for energy consumption support framework system and framework shear wall to control structural side shifting.

2 kinds of structural forms can be compared from view of project cost according to statistic result of concrete consumption of framework-shear wall structure and energy consumption support structure with obvious result. Energy consumption support system has high structural seismic performance while project cost is less than latter one greatly by comparing with framework-shear wall structure.

5. Promotion & application of energy consumption support framework structure in the project

Energy consumption support does not start up and only integral horizontal rigidity of the structure increases under multiple earthquakes. Internal force of energy dissipater basically does not reach yield strength. Energy dissipater starts up dissipation energy under effect of elastoplastic earthquake. Earthquake energy toward earthquake input direction is mainly dissipated by energy consumption support toward the direction. Energy consumption support toward another direction does not start up basically. Dissipated earthquake energy increases with structural lateral displacement and yield displacement of energy dissipater. So Friction energy consumption support is an effective passive control technique. Friction energy consumption reinforced concrete support with low cost has excellent promotion & application value [4].

There is simple processing process, low cost and convenient site installation for friction type energy dissipater. Therefore, new type of framework support form-energy dissipater support can be set to facilitate promotion & application [5]. Finite element method is often adopted for integral space analysis due to immature calculation method for the system during current phase. It cannot be used by design unit conveniently so as to limit future promotion & application of such structural system.

6. Conclusion

Research result of energy consumption & vibration absorption techniques of high-riser and middle building structure shows that energy consumption support device can be added between reinforced concrete framework columns to form an energy consumption support framework as an energy consumption & vibration reduction method with obvious effect and simple structure. Energy consumption support and energy dissipater of affiliate building of Service Commanding Center of Yunnan Security Guard Frontier Corps are produced, tested, assembled and detected by Seismic Institute of Kunming University of Science and Engineering. The project is an actual example for friction energy consumption support framework structure for finite element analysis, elastic response spectrum analysis and time interval analysis under effect of multiple earthquakes and elastoplastic earthquake. Results also show that energy consumption support framework system has excellent operation performance under earthquake effect to control horizontal lateral displacement of the structure under earthquake effect effectively.

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